

The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Civil Engineering



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Study Programme	: Bachelor of Science Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	: CVX 4240 Hydraulic Engineering I
Academic Year	: 2022/23
Date	: 10 th February 2024
Time	: 13:30-16:30hrs
Duration	: 3 hours

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **FIVE (5)** questions on **Five (5)** pages.
3. Answer **ANY FOUR (04)** questions. Each question carries **25 Marks**.
4. The answer for each question should commence from a **new page**.
5. **Mention any assumptions** made for calculations.
6. This is a **Closed Book Examination**.
7. Answers should be in clear handwriting.
8. Do not use Red colour pen.
9. An electronic non-programmable calculator may be used.
10. Take,

Density of water = 1000 kg/m^3

Acceleration due to gravity = 9.81 m/s^2

Dynamic viscosity of water = $1.0 \times 10^{-3} \text{ kg.m}^{-1}.\text{s}^{-1}$

[Q1]

(i) Briefly explain the *geometric similarity* and the *kinematic similarity*. [6 Marks]

(ii) It has been identified that the power (P) required to drive a mixer in a circular tank depends on the tank diameter (D), the rotational speed of the mixer (rotations per unit time) (N), the dynamic viscosity of the fluid (μ), and the fluid density (ρ). Using the Buckingham's Π theorem, develop an expression (using non-dimensional parameters) for power (P) required to drive the mixer installed in the circular tank. [10 Marks]

(iii) Sometimes pressure within pipelines can be negative due to the datum head. **Figure Q1** shows a part of a 75 mm diameter cast iron pipe used for water conveying. When the globe valve at *Point B* is fully opened, water flows at a velocity of 1.5 m/s.

a) What is the total head loss in the pipe from *Point A* to *Point C*?

b) Determine the pressure in the pipe at *Point A*. [9 Marks]

Take $\varepsilon = 0.26$ mm for cast iron pipe.

• Loss coefficients for pipe fittings,

▪ 90° elbow $K_L = 0.9$

Fully opened Globe valve $K_L = 10.0$

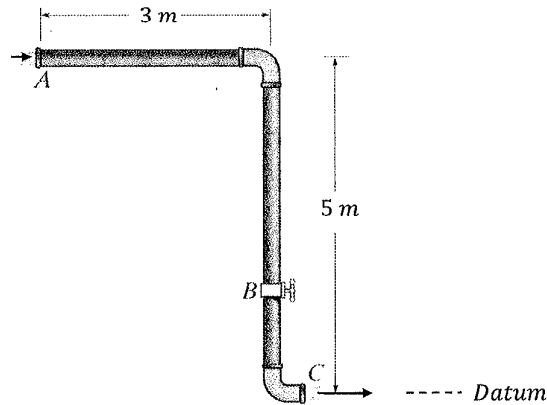


Figure Q1

[Q2] In **Figure Q2**, a water distribution system within a factory is depicted. Water enters the network at point 'A' and exits at points 'B', 'C', and 'D'. Utilize the quantity balancing method to determine the flow rate in each pipe. Please **perform calculations for up to two iterations**. [25 Marks]

For the initial iteration take,

$$Q_{AE} = 50 \text{ m}^3/\text{s}, \quad Q_{BC} = 70 \text{ m}^3/\text{s}, \quad Q_{ED} = 20 \text{ m}^3/\text{s}$$

Additional information,

$$\Delta Q = \frac{\sum K_i Q_i^2}{2 \sum |K_i Q_i|}$$

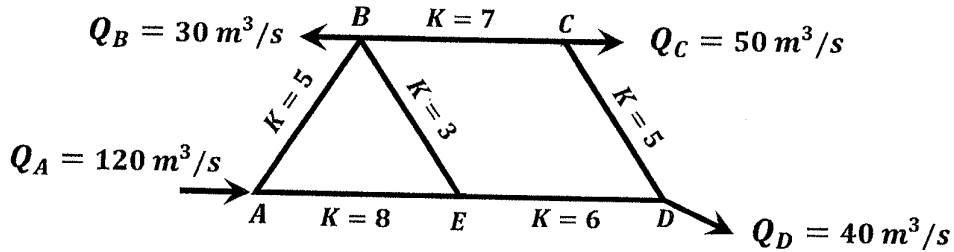


Figure Q2

[Q3]

- (i) Briefly describe what is meant by the **Energy grade line (EGL)** and **Hydraulic grade line (HGL)** in open channel flow. Draw a sketch of a horizontal profile of open channel flow, clearly indicating both lines. [5 Marks]

(ii)

Figure Q3 shows a horizontal profile of an open channel flow. Under uniform flow conditions in an open channel, using the Bernoulli equation, **prove that**,

- (a) The elevation difference along the channel length is equal to the energy lost due to friction.

- (b) The total head at point 1 (H_1) = $\frac{V_1^2}{2g} + (Z_1 + h_1)$. [6 Marks]

Where,

V_1 – Velocity at point 1, Z_1 – Datum head at point 1,

g – Acceleration due to gravity, h_1 – Depth to point 1 from the water surface

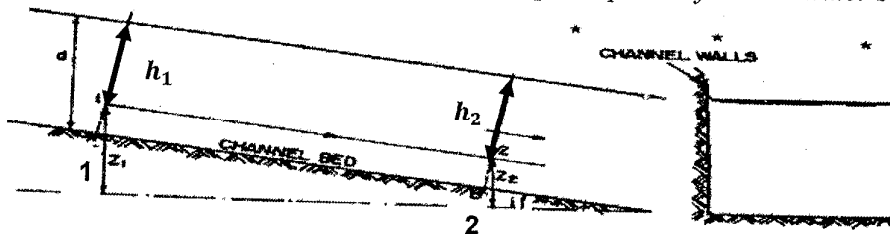


Figure Q3

- (iii) A rectangular channel, 12 m wide and 8 km long, is conveying water from one reservoir to another. The channel bed slope is 1:1250 and it discharges $30 \text{ m}^3/\text{s}$ of water at a depth of 1.8 m.

- What is the total head loss due to friction along the channel?
- To ensure safe operation, the maximum allowable water depth in the channel is 3.0 m. Using Chezy's formula, determine the maximum discharge in the channel.

[8 Marks]

Additional information,

Chezy's formula $V = C\sqrt{mi}$

Chezy's coefficient (C) is related to the depth of flow (d) and roughness of the channel (k) by, $C = 5.75\sqrt{g} \log_{10}(13.2d/k)$

[Q4]

- Briefly explain the purpose of designing a 'Hydraulic Jump' to form at the downstream side of the sluice gates.
- Using Froude Number, briefly explain the following.
 - What is a sub-critical flow and a super-critical flow?
 - What is the requirement to form a hydraulic jump?
- Figure Q4** shows a sluice gate of a reservoir and water is discharged through a 3 m wide channel. As shown in **Figure Q4**, water passing under the gate forms a hydraulic jump. If the flowrate of the channel needs to be maintained at $2.5 \text{ m}^3/\text{s}$, determine the following.
 - Froude number at the sluice gate.
 - Water depth after the hydraulic jump (y_2).
 - Froude number after the hydraulic jump.
 - Height of the hydraulic jump.
 - Percentage of head loss across the jump.

[18 Marks]

Additional information:

$$\frac{y_2}{y_1} = \frac{1}{2} \left(\sqrt{1 + 8Fr_1^2} - 1 \right)$$

$$\text{Head loss in the jump } (h_L) = \frac{(y_2 - y_1)^3}{4y_1y_2}$$

$$\text{Specific energy at the sluice gate} = \frac{V_1^2}{2g} + y_1$$

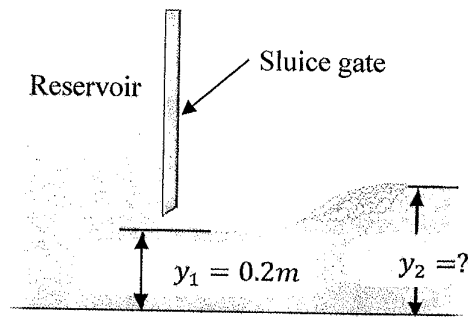


Figure Q4

[Q5]

- (i) Briefly explain what *cavitation* is? [4 Marks]
- (ii) Briefly explain the purpose of having a surge tank in some hydroelectric power plants? [4 Marks]
- (iii) As shown in **Figure 5**, a water pump (P) draws water from a reservoir and discharges it into a tank. The suction head and the discharge head of the pump are H_S and H_D , respectively. Point ① is located at the water surface level of the reservoir and point ② is located at the pump inlet.

By applying the Bernoulli equation between the points ① and ②, show that,

$$\text{Suction Head } (H_S) < \frac{P_a}{\rho g} - \frac{P_v}{\rho g} - \frac{V_2^2}{2g} - h_{fs}$$

Where,

- P_a – Atmospheric pressure
- P_v – Vapor pressure of water
- h_{fs} – Friction loss in the pipe of the suction side
- V_2 – Velocity at pump inlet
- ρ – Density of water
- g – Acceleration due to gravity

[9 Marks]

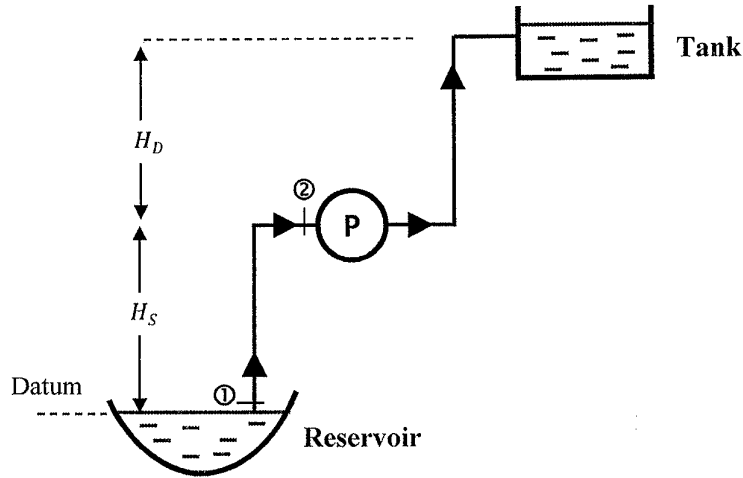
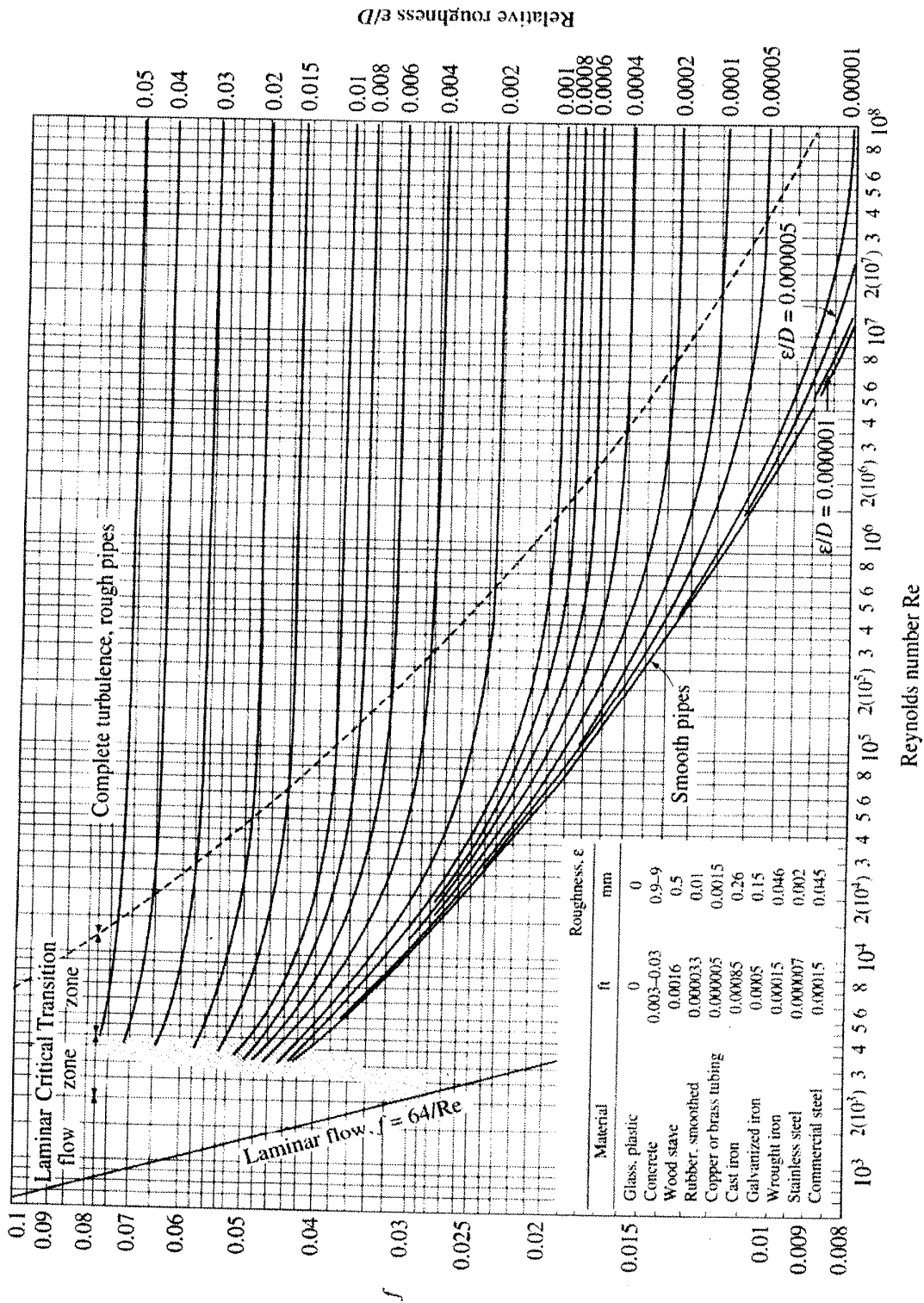


Figure Q5

- (iv) A water pump is to be installed to draw water from a well with a maximum depth of 5.5 m. Using the following information, determine whether the pump can be located at the ground level without causing cavitation.

The atmospheric pressure (P_a) is 100 kN/m^2 and the vapor pressure of the water (P_v) is 9.8 kN/m^2 . The maximum velocity at the inlet of the pump (V_2) is 8 ms^{-1} and the head loss is approximately 0.4 m of water for every 10 m of piping. [6 Marks]

- (v) Can the 'Net positive suction head' of the pump system (shown in Figure Q5) be increased by using two similar pumps connected parallelly? Provide a brief explanation to support your answer. [2 Marks]



Moody's Diagram